Rainwater Harvesting in a Typical Mine Area of Orissa

A PROJECT SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology
In
Civil Engineering

BY

Anwesha Sahoo
108CE047

Dipayan Choudhury
108CE038

UNDER THE GUIDANCE OF

Prof. Ramakar Jha

DEPARTMENT OF CIVIL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA
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CERTIFICATE

This is to certify that the Project Report entitled "**Rainwater Harvesting in a Typical Mine Area of Orissa** " submitted by **Mr. Dipayan Choudhury and Ms. Anwesha Sahoo** in partial fulfillment of the requirements for the award of Bachelor Of Technology Degree in **Civil Engineering** at National Institute Of Technology, Rourkela (Deemed University) is an authentic work carried out by them under our supervision and guidance.

To the best of our knowledge, the matter embodied in this Project Report has not been submitted to any other University/Institute for the award of any Degree or Diploma.

DATE :-

Prof. Ramakar Jha

ACKNOWLEDGEMENTS

My heart pulsates with the thrill for tendering gratitude to those persons who helped me in completion of the project.

The most pleasant point of presenting a thesis is the opportunity to thank those who have contributed to it. Unfortunately, the list of expressions of thank no matter how extensive is always incomplete and inadequate. Indeed this page of acknowledgment shall never be able to touch the horizon of generosity of those who tendered their help to me.

We extend our deep sense of gratitude and indebtedness to our guide **Prof. Ramakar Jha** Department Of Civil Engineering, National Institute of Technology, Rourkela for his kind attitude, invaluable guidance, keen interest, immense help, inspiration and encouragement which helped us in carrying out our present work.

We are extremely grateful to **Prof. N. Roy,** Professor and Head of the Department of Civil Engineering and **Prof. S.P Singh**, faculty advisor and members of Civil Engineering Department, National Institute of Technology, Rourkela, for providing all kinds of possible help throughout the two semesters for the completion of this project work.

It is a great pleasure for us to acknowledge and express our gratitude to our classmates and friends for their understanding, unstinted support and endless encouragement during our study.

Lastly, we thank all those who are involved directly or indirectly in the successful completion of the present project work.

Dipayan Choudhury | Anwesha Sahoo

CONTENTS

ABSTRACT:

This paper discusses about the rainwater harvesting system and its implementation in a typical Mine area of Orissa, India as part of the solution to avoid water crisis in the future. It first reviewed the scenario of water availability, its distribution and shortages in the study region. In India and in the study region, we are blessed with an ample supply of water during Monsoon. However, rainwater is not available during non-monsoon period.

Increasing water consumption by the industry, maintenance of dust due to crushing of rocks, plantations, vegetation and household users in the study region, had made existing water supply infrastructure strained. A study has been done to estimate the available runoff from the catchment area of a Mine in Orissa. ILWIS-GIS was used to delineate contours, drainage, land use and develop digital elevation model (DEM), flow accumulation, flow direction and aspect maps. Most suitable sites for water storage were obtained considering Best Management Practice (BMP) approach. Quantitative analysis was carried out using Rational method with runoff coefficient values to estimate the runoff volume available at different locations. The results indicate four sites suitable for water storages with some additional earthwork. Subsequently, for better accuracy and for and a robust approach, quantitative analysis was carried out using SCS-CN method with suitable CN value so obtained from the land use and other parameters to estimate the runoff volume available at different locations. The results indicate four sites suitable for water storages with some additional earthwork. Different scenarios were generated to obtain different runoff volumes and corresponding water spread area in the region. The length, breadth and depth required for each area is calculated using optimization approach to minimize the earthwork and maximize the plane surface.

CHAPTER 1

INTRODUCTION

Water is an important element for all human beings in the world. Our body consists mostly of water. We need water for drinking, cooking, washing, agriculture and to run our industries. We usually take it for granted because of its availability; but when in scarcity it becomes our most precious resource. Every raindrop that falls from the cloud is very soft and the cleanest water sources in this world (Texas Water Development Board, 2005). The falling raindrop acquires slight acidity as it dissolves carbon dioxide and nitrogen (MHLG, 2008). Rainwater is a part of hydrologic cycle; the never-ending exchange of water from the atmosphere to the ocean and back again as rainwater. The precipitation like hail, rain, sleet, snow and all the consequently movement of water in nature forms are from part of this cycle.

Rainwater can be captured by using the rainwater harvesting system. Generally, rainwater harvesting system is the direct collection of rainwater from roofs and other purpose built catchments, the collection of sheet runoff from man-made ground or natural surface catchments and rock catchments for domestic, industry, agriculture and environment use. The systems can be categorized as small, medium and large scale (Gould 1999). Normally, the size of rainwater harvesting was based on the size of catchment area (Thamer *et al*., 2007). In scientific term, rainwater harvesting refers to collection and storage of rainwater and also other activities aimed at harvesting surface and groundwater, prevention of losses through evaporation and seepage and all other hydrological studies and engineering interventions, aimed at conservation and efficient utilization of the limited water endowment of physiographic unit as a watershed (Agrawal and Narain, 1999).

Rainwater harvesting is a traditional practice that dates back hundreds of years. Archeological evidence attests to the capture of rainwater as far as 4,000 years ago and the concept of rainwater harvesting in China may date back 6,000 years (Texas Water Development Board, 2005a; Sharma and Jha, 2010). Rainwater has been the main source of water supply for potable and non-potable uses in the old days because the water supply systems were not developing yet. The method of rainwater harvesting at that time was very simple. Usage of the collected water volume from rainwater harvesting was direct and without any treatment. Usually, the rainwater was mostly collected from roofs and some was directly collected (Thamer *et al*., 2007). Nowadays, the responsibility rests on the State Water Board to operate and run water supply for residential areas and commercial. With this, rainwater harvesting system has been ignored.

Rainwater harvesting system has been implemented in many countries such as USA, Japan, China, India, Germany and Australia to support the increasing water demand. The integration between rainwater harvesting system and existing conventional water supply systems will help to meet the demand and contribute in the sustainability of the water supply. There are six main elements in rainwater harvesting system (Figure 1). They are catchment area, gutter and downspout, filtration system, storage system, delivery system and treatment.

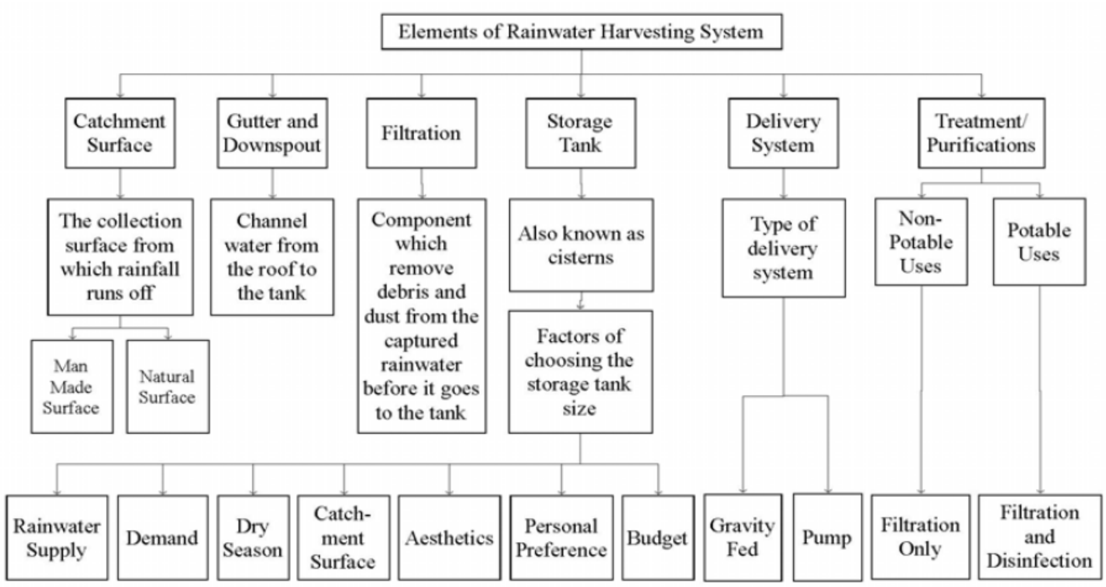

Figure 1: Elements of Rainwater Harvesting System

1.1 ADVANTAGES

1.Provides self-sufficiency to water supply

2.Reduces the cost for pumping of ground water

3.Provides high quality water, soft and low in minerals

4.Improves the quality of ground water through dilution when recharged

5.Reduces soil erosion & flooding in urban areas

6.The rooftop rain water harvesting is less expensive & easy to construct, operate and maintain

7. In desert RWH is the only relief

8. In saline or coastal areas & Islands, rain water provides good quality water

1.2 TECHNIQUES

- Storage of rainwater on surface for future -This is a traditional technique and structures used are underground tanks, ponds, check dams, weirs etc.
- Recharge to ground water- This is a new technique and it is done by constructing recharge pits, trenches, dug wells, hand pumps, recharge wells etc.

1.3 RWH METHODOLOGIES:

- **Roof Rain Water Harvesting-** The roof top area is used as the catchment area for the rainfall in urban areas. The collection and storage sizes and systems need to be optimized for the Rainwater Harvesting systems in such cases.

- **Watershed based Rain Water harvesting-** A watershed consists of a land and water region bounded by ridge lines or other such drainage divides within which the water flowing as surface runoff gets collected and flows out of the watershed along a network of channels or through a single outlet into a lager river (or) lake. Rainwater harvesting for a common single watershed is generally taken up in most of the rural areas. As the cost of land is less and it is available in plenty, surface spreading techniques are generally effectively adopted in such regions.

CHAPTER 2

LITERATURE REVIEW

2.1 RURAL WATER HARVESTING

2.1.1 NADIS

Rajsamand district in western Rajasthan has a rich legacy of rainwater harvesting structures. Nadis (ponds) once served as the principal drinking water sources in this area. They received their water supply from erratic, torrential rainfall. Since the runoff was from sandy and eroded rocky basins, large amounts of sediments were regularly deposited in them, resulting in quick siltation. A local voluntary organization, the MewarKrishakVikasSamiti (MKVS) has been working in the district for the welfare of local farmers. They have constructed 20-30 nadis with a command area in excess of 500 ha. The organization has added systems like spillways to the nadis to prevent damage . To prevent siltation, the MKVS has promoted afforestation of the drainage basin and constructed silt traps. Since farmers construct these structure on their own fields using locally available materials, the cost of construction ranges between Rs 2,500-10,000 and is thus affordable.

2.1.2. POLYMER-KUNDIS

In the villages of Rajasthan, the villagers are encouraged to build and renovate tanks, ponds, permanent ponds and dugwells. The tank consists of a circular catchment area sloping towards the centrally located storage structure. The quality of water from kundi is good and if maintained properly no serious water contamination occurs. Its maintenance is easy. Local materials such as clay, silt, lime,ash and gravel are traditionally used to construct the catchment area of a tank. They do not make completely impermeable layer. As a result some part of rainwater is lost due to uncontrolled seepage. To prevent this, Water based non-toxic polymer solution that permeate the highly porous sandy soils are used to increase runoff from tanks. These polymers act as binders and reduce permeability and infiltration rate of sandy soils. Use of water repelling chemicals, in combination to some binding agents, result in better runoff.

2.2. URBAN WATER HARVESTING

2.2.1. MADHYA PRADESH

Action for Social Advancement (ASA) is a nongovernmental organization based in Madhya Pradesh in Central West India. In 1996, ASA worked with 42 tribal villages (nearly 25,000 people) with a land area Of nearly 20,000 hectares in Jobat, one of the sub-districts of Jhabua district in Madhya Pradesh, to carry out watershed work at the small river basin level. It implemented water storage, percolation tanks and masonry check dams with the intention of increasing the sub-surface and ground water flows and to ensure their continuity throughout the year.ASA also focused on land development to check soil erosion and increase infiltration of rainfall. The impact of ASA's watershed management at the river basin level can be assessed through the improvement in subsurface flow of water and productivity in the area.

2.2.2. KARNATAKA

The Karnataka Watershed Development Project (KAWAD) (Appendix II: case 3.3) is located in the northern districts of the Karnataka state in the south of India. The northern part of the state experiences water scarcity. To address this concern, KAWAD has been trying out different institutional mechanisms to identify the appropriate approach for resolving water use conflicts.

2.2.3. DENMARK

Following significant population increases and housing standard improvements, Århus, Denmark's second largest city, was challenged by increased water demand and consumption. In the 1960s-early 1970s, this increased demand was met by pumping groundwater from the aquifers of the Giber basin which gradually depleted. This led the authority to adopt rainwater harvesting .Now, the Giber basin contains several flood retention reservoirs, constructed in accordance with municipal regulations for storm water control, one of which was found to be feasible for storing rainwater for later controlled release, as a supplement to the natural flow.

2.2.4. AT N.I.T. ROURKELA by Mr. Ranjit Sharma

The technical aspects of this paper are rainwater harvesting collected from rooftop which is considered to be catchment areas from all hostels and Institutes departmental building at N.I.T. Rourkela Campus. First of all, required data are collected i.e. catchment areas & hydrological rainfall data. Water harvesting potential for the hostels and faculty apartments was calculated, and the tank capacity with suitable design is being considered. Volume of tank has been calculated with most appropriate method of estimation. Optimum location of tank on the basis of hydrological analysis and GIS analysis was done in the campus. Finally, Gutter design, its analysis, first flush and filtration mechanism are also dealt with in detail.

CHAPTER 3

THE STUDY AREA

The study area is in Tensa valley Sundargarh district, Orissa (Figure 2). It has a hilly topography with its elevation varying from 590 above mean sea level to 840 above mean sea level. There are number of valleys with dry drainage channels within the area. Entire area is covered by undulating hilly tract intersected by gorges and passes. Besides many seasonal nalas, there are about four perennial nalas in the region. Basically it's a rugged mountainous region being bisected by number of geomorphic valleys; the central part of the area has in-situ laminated and massive ore bodies covered with laterite. Tensa has been declared the best mine by the Director General of Mines Safety, Govt. of India. JSPL's iron ore mines, at Tensa valley in district Sundargarh, Odisha, 100 km from Rourkela, fulfill the company's requirement of iron ore for producing sponge iron. Produced as part of JSPL's backward integration plans to make the company self reliant, iron ore from Tensa mines ensures consistency in the quality of raw material used in sponge iron kilns. Operational since 1990, these mines are popularly known as TRB (Tantra, Raikela, Bandhal) Mines. The mining lease area forms a part of Survey of India Toposheet No. 73 G/1 and lies between latitude 21º53'00" to 21º53'48" and longitude 85º10'07" to 85º11'55".

3.1. TOPOGRAPHY AND DRAINAGE:

The project site has a hilly topography. The elevation varies from 840 MRL (north eastern part) to 590 MRL (southwest part). There are number of valleys with dry drainage channels within the area. Entire area is covered by undulating hilly tract intersected by gorges and passes. Besides many seasonal nalas, there are about four perennial nalas in the region. Basically it's a rugged mountainous region being bisected by number of geomorphic valleys. The central part of the area has insitu laminated and massive ore bodies covered with laterite.
The image of the area from google earth is given.

3.2. CLIMATE

The area experiences sub-tropical climate with abundant rainfall during monsoon months. The summers are not very hot due to very thick forest cover in the area. April-May are the hottest months and December-January are the coolest months. The mean of minimum temperatures recorded ranges from 10.82ºC in December to 23.84ºC in May and the mean of maximum temperature ranges from 25.81ºC to 36.64ºC.

The area enjoys high precipitation during monsoon season. The area may be divided in four seasons. The hot season lasts from March to May; period from June to September is the south-west monsoon season. October and November constitute the post monsoon season and the cold season is from December to February. The nearest IMD station is at Keonjhor

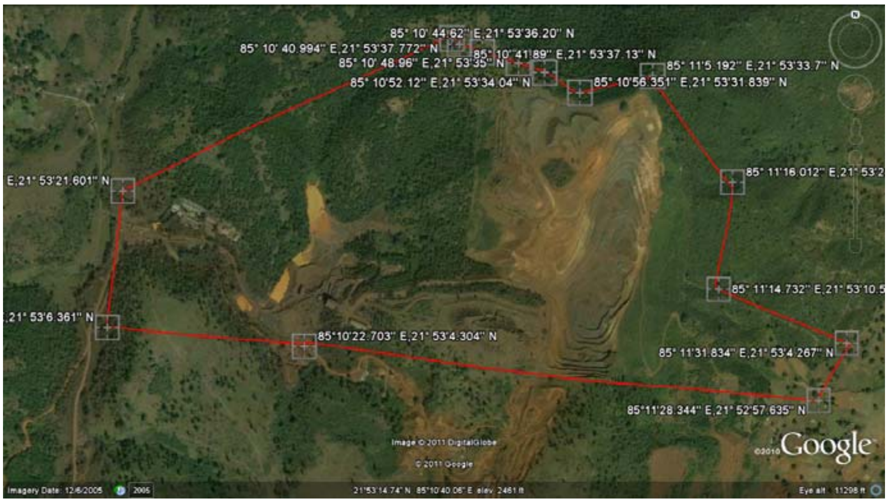

Figure 2: The study area for Rain Water Harvesting (Source: Google earth)

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3.2.1. Temperature

The mean of minimum temperatures recorded ranges from 10.82ºC in December to 23.84ºC in May and the mean of maximum temperature ranges from 25.81ºC in December to 36.64ºC in May.Month wise average maximum and minimum temperatures recorded during 1993-2002 at IMD Keonjhar are given in graph below. The graph indicates that the minimum temperature is in December with maximum in May.

3.2.2. Relative humidity

The monthly average relative humidity recorded at Keonjhar (1993-2002) and the relative humidity variations are graphically presented in figure below for Keonjhar. The data indicates that high monthly relative humidity occurs between June to October. The average values at 8.30 hrs and 17.30 hrs are 67% and 50% respectively.

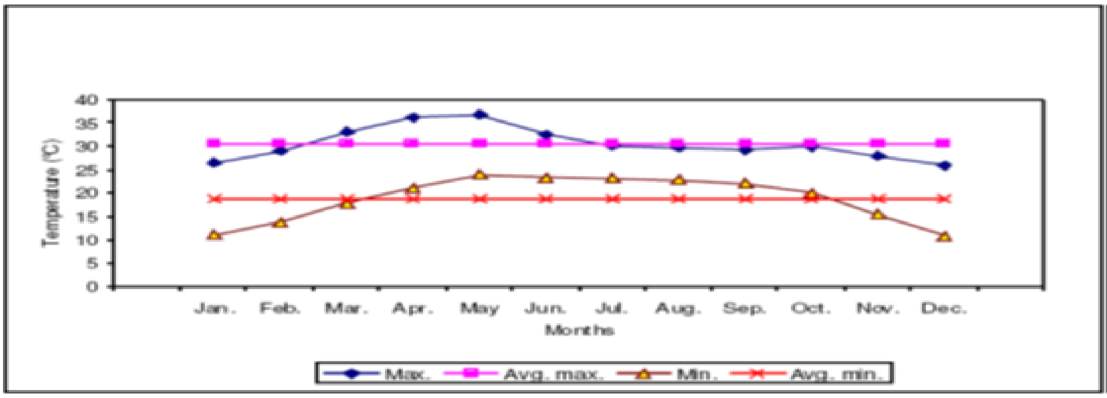


Figure 3: Monthly Avg. Max and Min Temperature(°C)

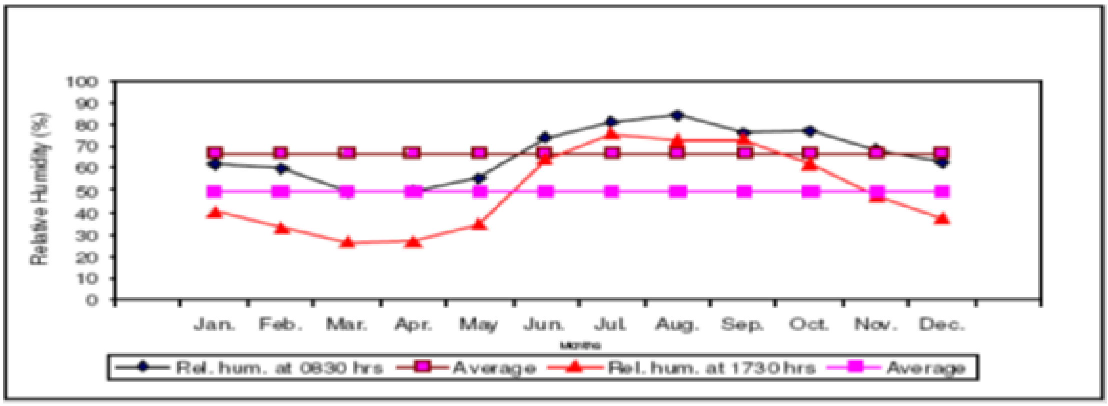


Figure 4: Monthly Relative Humidity(%)

3.2.3. Rainfall

Details of annual rainfall and the monthly variations of the rainfall as recorded at IMD station, Keonjhar for the period of 1993-2002 are given graphically as in figure below. It can be seen that more than 71% of the annual rainfall is received by the south-west monsoon between June to September, August being the rainiest month of the year.

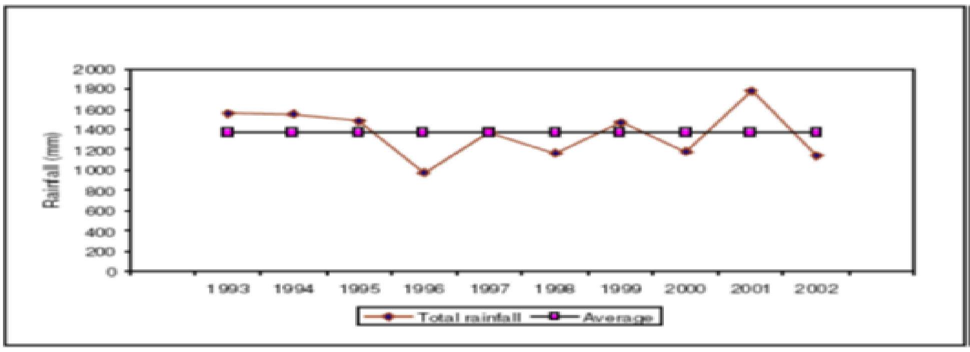


Figure 5: Annual Total Rainfall (mm)

3.3. SOIL QUALITY

The soil of the area is less fertile. The area is occupied by red sandy soil, gravelly and lateritic soil. The soil contain a large quantity of iron but is generally deficient in nitrogen and phosphorous. Soil in general loose in texture and well drained. Plenty of iron concentration are present in the soil.

3.4. WATER ENVIRONMENT

The requirement of industrial water is 180 cumd at present and will increase to 222 cumd. The HFL of Samji nala is 589 m RL .The ground water table will not be intersected by the proposed mine workings as the lower most level of the quarry will be 688 m RL whereas the ground water level will be at 589 m RL. Hence there would not be any adverse impact on the ground water regime.

CHAPTER 4

DEVELOPMENT OF TOPOGRAPHICAL INFORMATION USING ILWIS-GIS

A geographic information system (GIS) is computer software that is designed to capture, store, manipulate, analyze, manage and present all types of geographically referenced data. The interactions between data and geographic locations are managed and manipulated by GIS.
In our project ILWIS 3.4 is used for GIS analysis. The map of JINDAL-TENSA was scanned and converted into a digital elevation model (DEM). DEM gives clear idea on the surface topology which can be effectively used for analysis by giving thorough distinct information on the variation in the elevation at the different locations of the surface. The high contour lines on the digital elevation model denotes surfaces of high altitudes i.e. Mountainous region and low lining contour lines denotes the surfaces with low altitudes such as valley region.

The steps for generating the digital elevation model map:

Step1: Importing the scan map to the ILWIS Software

To generate Digital Elevation Model (DEM) from the maps, contour map of the study area with 5 meter interval was drawn. Figure 6 shows the contour map of the study area. The high contour lines denote surfaces of high altitudes i.e. mountainous region and low lining contour lines denotes the surfaces with low altitudes such as valley region.

Step 2: Processing the scan map and generation of different maps such as: contour line map (figure 7), boundary line segment map (figure 8), road and drainage maps(figure 8), mines area point map.

Contour lines are drawn on a segment value map. Each contour line is assigned with its R.L. and thus different colors are assigned to them to make the distinction between high elevation line and low elevation line easy.

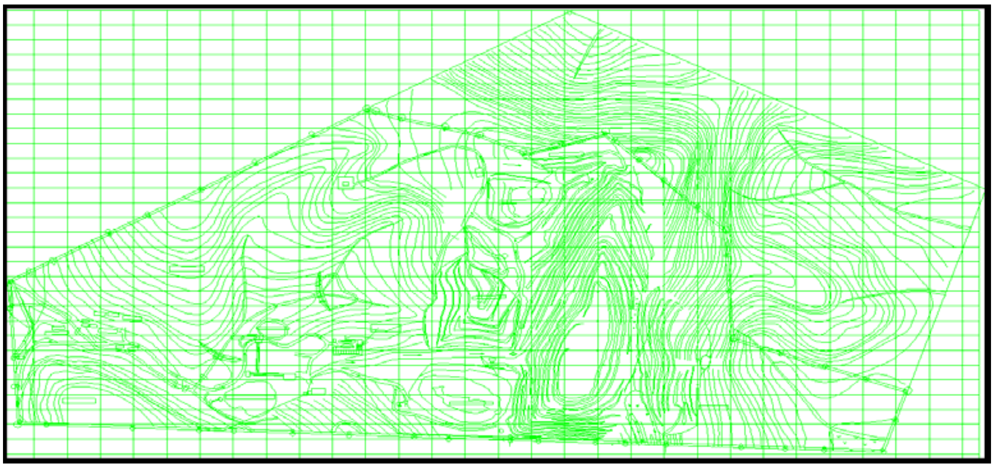


Figure 6: Contour maps of the study area with 5 meter interval

Figure 7:contour map

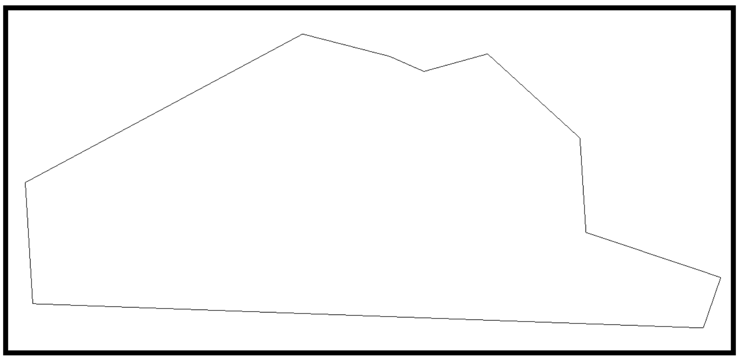


Figure 8: Boundary map

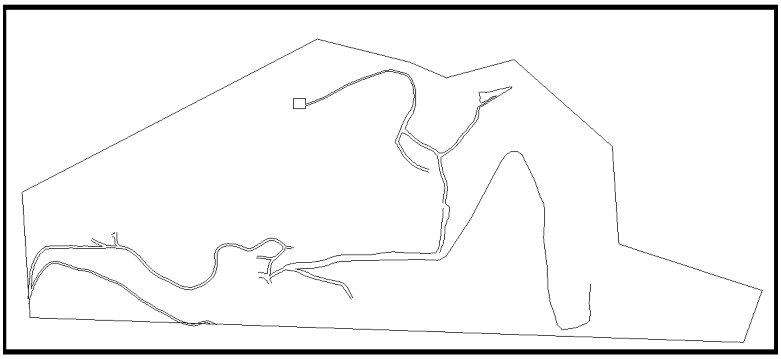


Figure 9: Road Map

Step 3: Overlaying of maps:

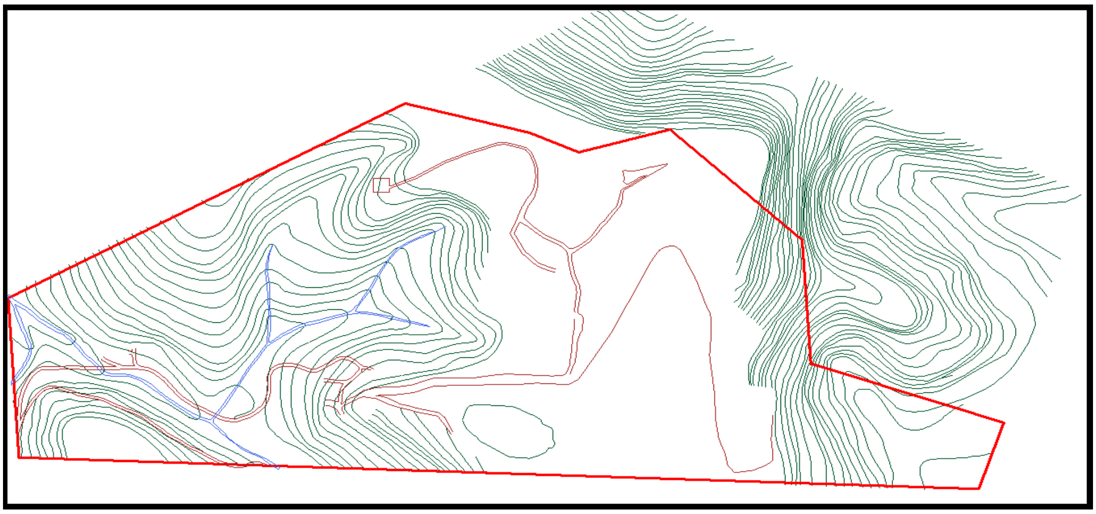


Figure 10: overlayed segment map

Step 4: Development of DEM (Digital elevation model):

Digital elevation model was created from the contour line map using the following algorithm of contour interpolation in ILWIS. A digital elevation model is a Three Dimensional digital model or representation of a terrain's land surface generated from available terrain elevation data. This term digital surface model represents the surface of the earth and includes all the objects on it. A DEM can be symbolized as a raster (which is a grid of squares, also known as a height map when representing elevation) or as a vector-based triangular irregular network (TIN). The TIN DEM dataset is generally referred to as a primary (measured) DEM, whereas the Raster DEM is referred to as a secondary (computed) DEM. DEMs are commonly built using remote sensing techniques, but they may also be built by using land surveying. DEMs are mostly used in geographic information systems, and often are the most common basis for digitally-produced relief maps.

Contour interpolation used in making a DEM initially rasterizes contour lines all over the segment map. This results in obtaining values for all the pixels that are placed on the segments. Then these values have to be calculated for all other pixels falling in between the segments. For each of the undefined pixel, the distance is calculated between and towards the two nearest contour lines. The distances are calculated forwards and backwards, until no more changes occur. Then a linear interpolation is performed using the two values of distance. This returns the value for the required undefined pixel as shown in Figure 11. Finally, the DEM developed for the study region is shown in Figure 12. Different colors denote the different elevation levels by reading from the legends placed along the side of the map.

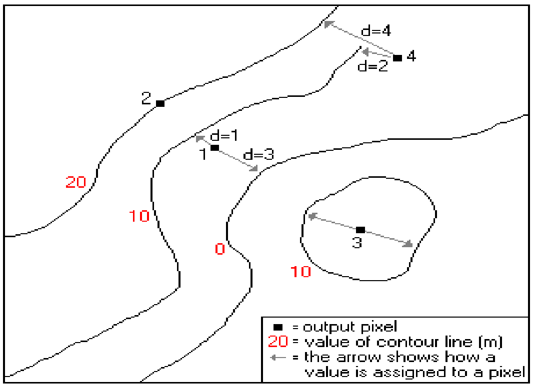


Figure 11: Example of contour interpolation technique in ILWIS

So, after a detailed analysis and study, finally a conclusion was drawn that at lower elevation region (southern west) water flowing down from higher elevation can be stored in specific areas by constructing boundary. This was further substantiated by finding the existing water storages and other depression in the region during field survey.

Hence by GIS Analysis, we get an overview of potential rainwater harvesting and suitable location for water storage in the region. Four catchments area are obtained using BMP approach considered for analysis (Figure 13):

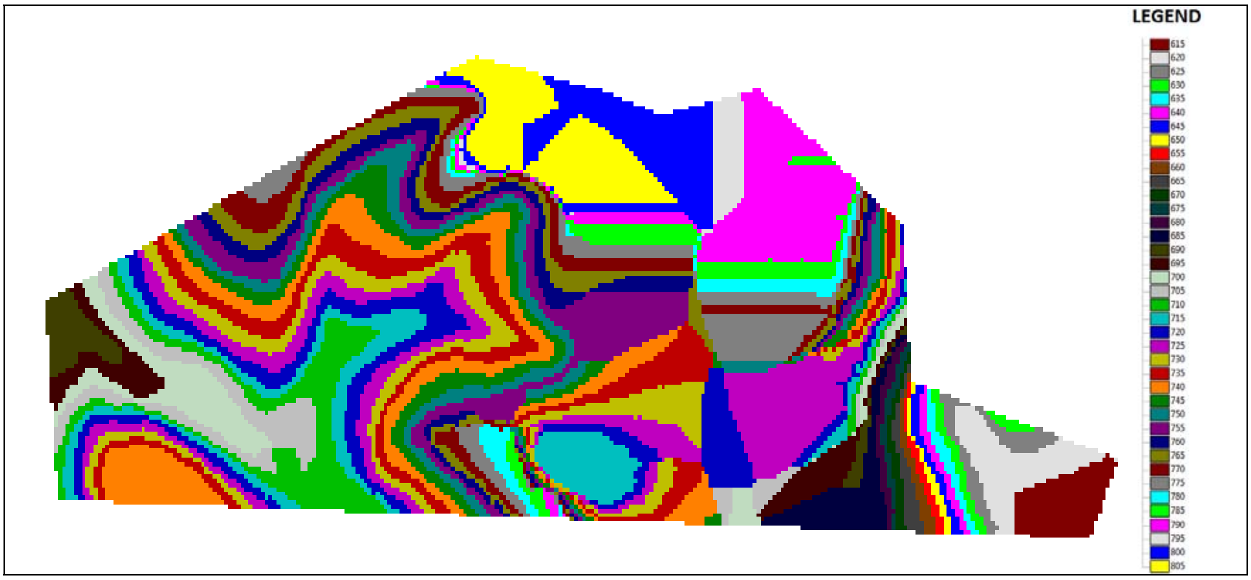


Figure 12: Digital Elevation Model of the study region

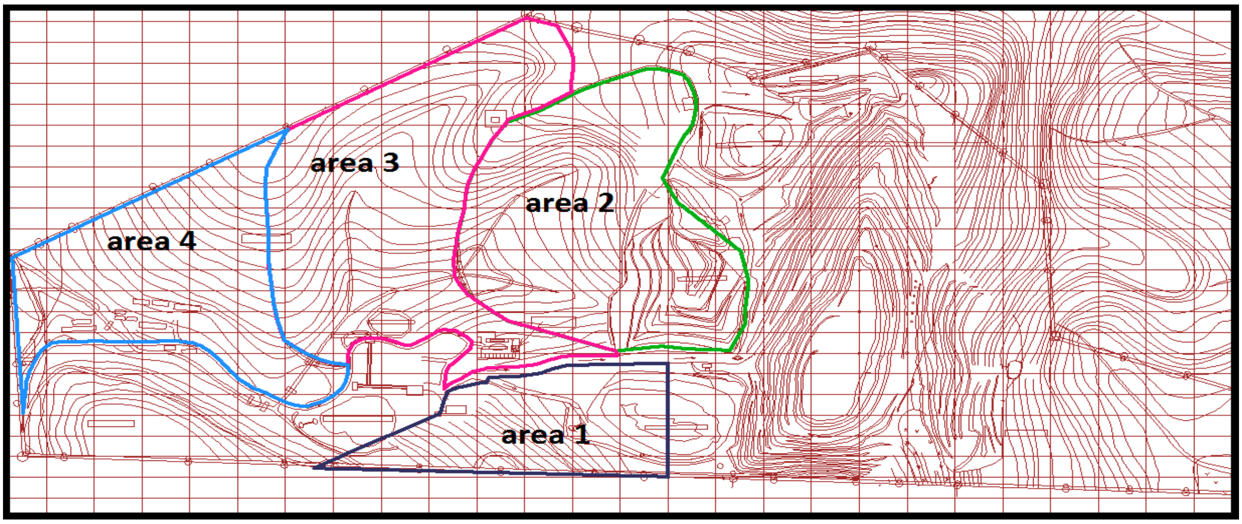


Figure 13: catchment areas

AREAS (in m^2)

Area 1	Area2	Area3	Area4
128000 m²	301800 m²	331600 m²	224300 m²

CHAPTER 5

ASSESSMENT OF RAINWATER IN THE STUDY REGION

5.1. Computation of rainfall values

Monthly rainfall data were collected from various sources for the year 1992 to 2011 for the study region. For the present work, time series plots of rainfall data for each year were drawn and their monthly/annual amount was computed. The monthly variation of rainfall (in mm) of the region for a period of six years (2005 to 2011) are shown in bar graph below (Figure 14). It can be seen that maximum rainfall is received during the months june, july ,august, September.

Rainfall in mm during monsoon season of different years are shown in the figure 15. Maximum rainfall was received in the month july with an average rainfall of 327.1667 mm, followed by august with a rainfall of 273.45 mm, june with 201.2833mm and septenber with 160.3667 mm average rainfall.The mean annual and monsson rainfall are shown in table 1.

5.2. Estimation of runoff using Rational Method

The Rational equation is the simplest method to determine peak discharge from drainage basin runoff. The equation is as follows:

$$Q=CIA;$$

The Rational equation requires the following units,

Q = Peak discharge, cfs,
C = Rational method runoff coefficient,
I = Rainfall intensity, inch/hour,
A = Drainage area, acres.

It is used to calculate the peak discharge for small catchments. It can be considered as a representative of all other empirical relations. The runoff rate increases from zero to the peak value upto the time of concentration and thereafter remains constant for the remaining period of rainfall excess. After the cessation of rainfall, the runoff reduces and gradually becomes zero after a time equal to the time of concentration from the end of peak of discharge.

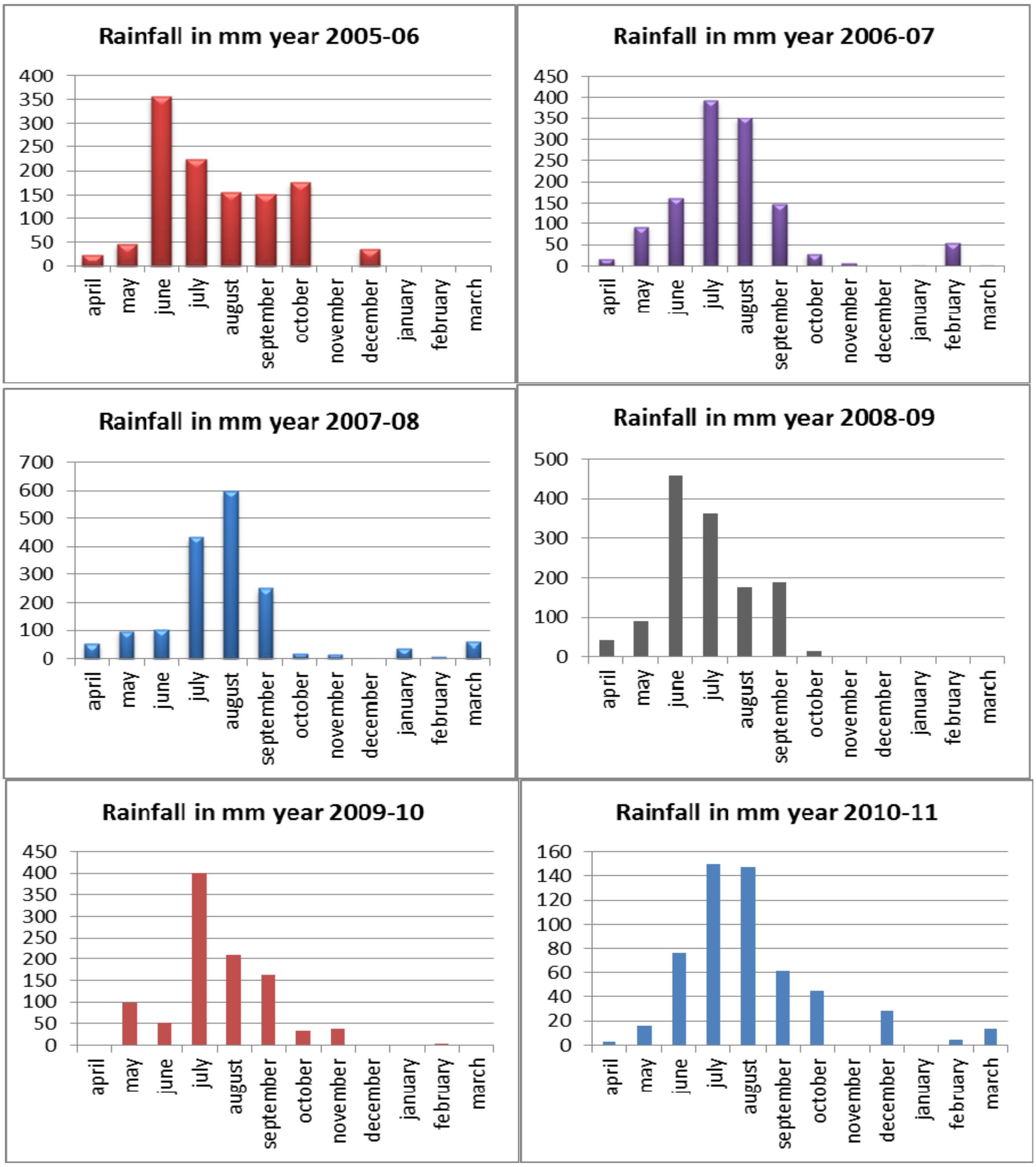


Figure 14: Monthly variation of rainfall (in mm)

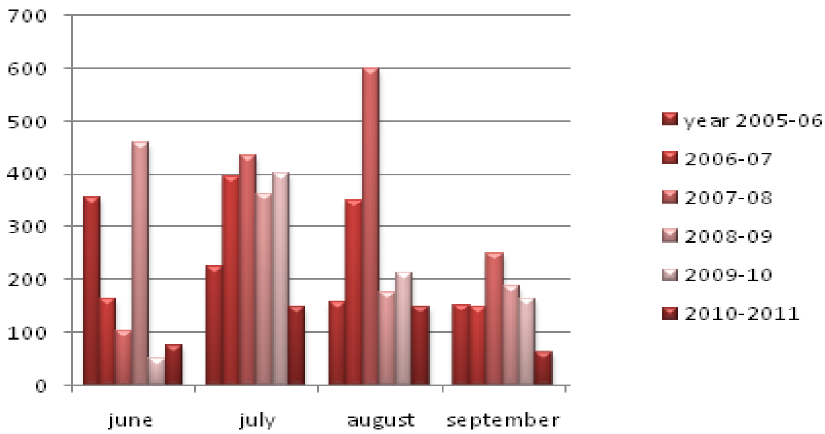


Figure 15: Rainfall in mm during monsoon season

Table 1: MEAN ANNUAL AND MONSOON RAINFALL

YEAR	ANNUAL RAINFALL (mm)	MONSOON RAIN (mm)
2005-06	1172.6	888.5
2006-07	1254.2	1054
2007-08	1676.1	1385.8
2008-09	1332.2	1182.7
2009-10	1000.4	827.8
2010-11	545	434.8
TOTAL	6980.5	5773.6
MEAN	**1163.42**	**962.27**

The Rational method runoff coefficient (c) is a function of the soil type and drainage basin slope. A simplified table is shown below.

The Rainfall intensity (i) is typically found from Intensity/Duration/Frequency curves for rainfall events in the geographical region of interest. The duration is usually equivalent to the time of concentration of the drainage area. The storm can also be considered for the analysis. A 10-yr, 25-yr, 50-yr, or even 100-yr storm frequency can be specified as per the impact of development as decided by the local authorities.

Here we used a runoff coefficient of 0.8 (since it is a barren land). The runoff volume computed for each location using Rational Method is shown in table 2 and figure 16.

Table 2: RATIONAL METHOD RUNOFF COEFFICIENTS

Ground Cover	Runoff Coefficient, c
Lawns	0.05 - 0.35
Forest	0.05 - 0.25
Cultivated land	0.08-0.41
Meadow	0.1 - 0.5
Parks, cemeteries	0.1 - 0.25
Unimproved areas	0.1 - 0.3
Pasture	0.12 - 0.62
Residential areas	0.3 - 0.75
Business areas	0.5 - 0.95
Industrial areas	0.5 - 0.9
Asphalt streets	0.7 - 0.95
Brick streets	0.7 - 0.85
Roofs	0.75 - 0.95
Concrete streets	0.7 - 0.95

Table 3: RUNOFF CALCULATIONS BY RATIONAL METHOD

	A1	A2	A3	A4
Annual rainfall (mm)	1163.42	1163.42	1163.42	1163.42
Area (sqm)	124700	293900	323000	218500
Runoff(cum)= 0.8 x I x A	116021	273445	300519	209788

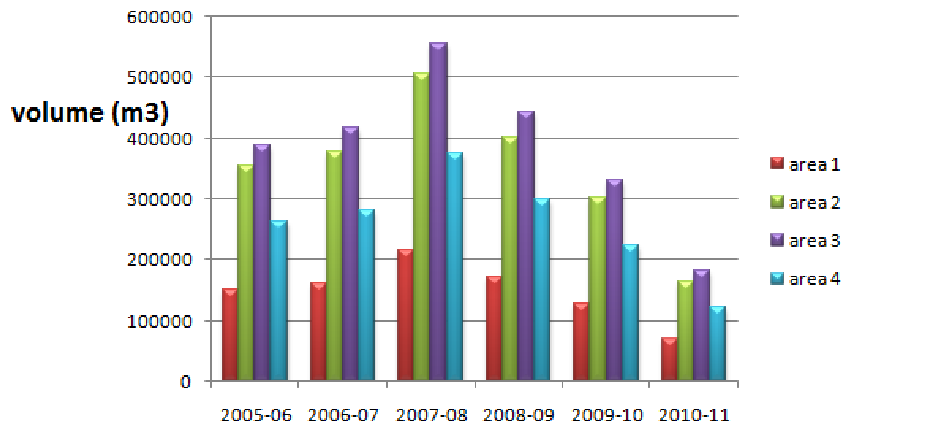


Figure 16: Runoff volume estimated for each area obtained by Rational Method

5.3. Estimation of runoff using SCS-CN Method

It is developed by Soil Conservation Services of USA in 1969. It is based on the Water Balance Equation i.e

$$\mathbf{P=Q+F+I_a\ ;}$$

where

P = Total Precipitation

Q = Direct Surface Runoff

F= Cumulative Infiltration

I_a= Initial Abstraction

The equation used to obtain discharge is:

$$\mathbf{Q=(P-\lambda S)^2/(P+(1-\lambda)S)\ ;}$$

where S= Potential Maximum Retention

Curve Number (CN) is given as :

$$\mathbf{CN=25400/(S+254)\ ;}$$

which is a dimensionless parameter to express 'S' which again depends on soil-vegetation and land use complex of a catchment.

The Curve Number (CN) depends on :

i. Soil Type
ii. Land Use/Cover
iii. Antecedent Moisture Condition

For the site under consideration, the value of λ as 0.2 was assumed and level of AMC as AMC-II. Since the site has a rocky terrain, the runoff potential would clearly be very high, the hydrologic soil group as Group – D was assumed. Next, the forest cover of each individual subareas for the years 2005 and 2011 was obtained from Google earth and the curve numbers were calculated for each of them respectively. The max retention 'S' and the discharge 'Q' was subsequently determined and further design storage dimensions were obtained.

The curve numbers calculated for each catchment area for different forest cover in year 2005 and 2011 are shown in table 4.The runoff (in mm) calculated in 2005 and 2011 are shown in table 5 and 6.

Table 4: CURVE NUMBERS CALCULATED

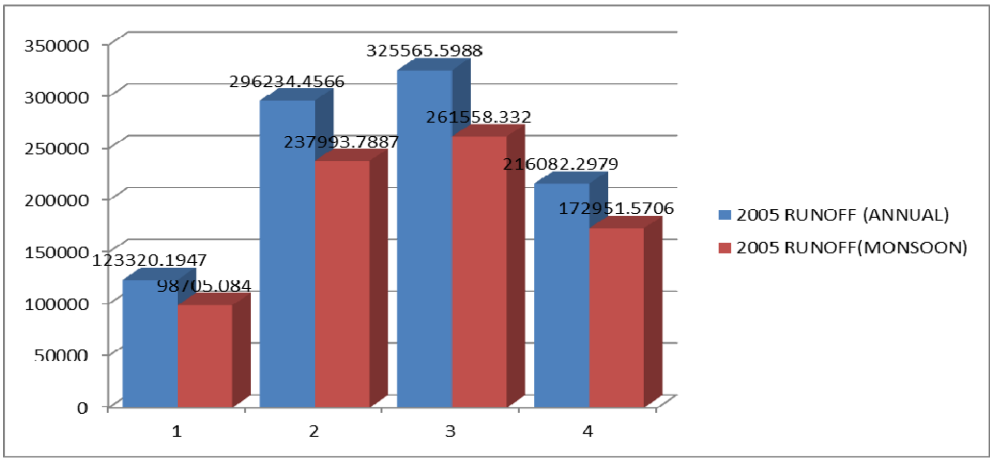
AREA	2005 FOREST COVER	2005 CN	2011 FOREST COVER	2011 CN
A1	97%	61	32%	93
A2	73%	64	64%	67
A3	68%	64	59%	90
A4	82%	61	52%	67

Table 5: RUNOFF IN 2005

CATCHMENTS	ANNUAL RAINFALL (mm)	MONSOON RAINFALL (mm)	RUNOFF (ANNUAL) (cu.m)	RUNOFF (MONSOON) (cu.m)
A1	1163.41	962.26	123320.19	98705.08
A2	1163.41	962.26	296234.45	237993.78
A3	1163.41	962.26	325565.59	261558.33
A4	1163.41	962.26	216082.29	172951.57

Table 6: RUNOFF IN 2011

CATCHMENTS	ANNUAL RAINFALL (mm)	MONSOON RAINFALL (mm)	RUNOFF (ANNUAL) (cu.m)	RUNOFF (MONSOON) (cu.m)
A1	1163.41	962.26	142255.86	117180.41
A2	1163.41	962.26	301446.88	243018.22
A3	1163.41	962.26	365061.57	300134.42
A4	1163.41	962.26	224110.73	180671.93



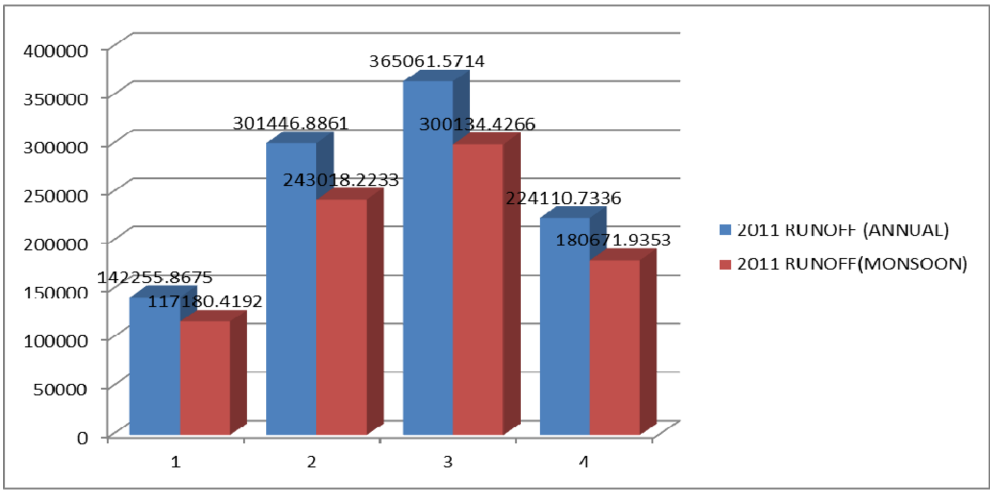


Figure 17: Runoff Volumes in 2005 & 2011 by SCS-CN Method

CHAPTER 6

OPTIMISTIC DETERMINATION OF SIZE AND LOCATION OF STORAGE

A good storage site should possess the following traits:

- The capacity catchment area ratio should be such that the pond can fill up in about 2-3 months of rainfall. The capacity should not be too small to be choked up with sediments very soon.
- It should be located where it could serve a major purpose
- The site should not have excessive seepage losses.
- The catchment area should be put under conservation practices.

Different scenarios were generated to obtain different runoff volumes and corresponding water spread area in the region. From an economic view point, the tank should be located where maximum storage volume is obtained for minimum volume of earthfill, since the major share of the cost goes into the earthfill. This condition, generally, can be met at a site where the stream/ drainage channel is narrow, steep, side slopes are steep and stable, and the stream beds is of consolidated and nearly impervious formation. Such sites also minimize the pond area. The water storage structures are preferred to be made on relatively plane grounds for each catchment area considered as shown in the figure 18.

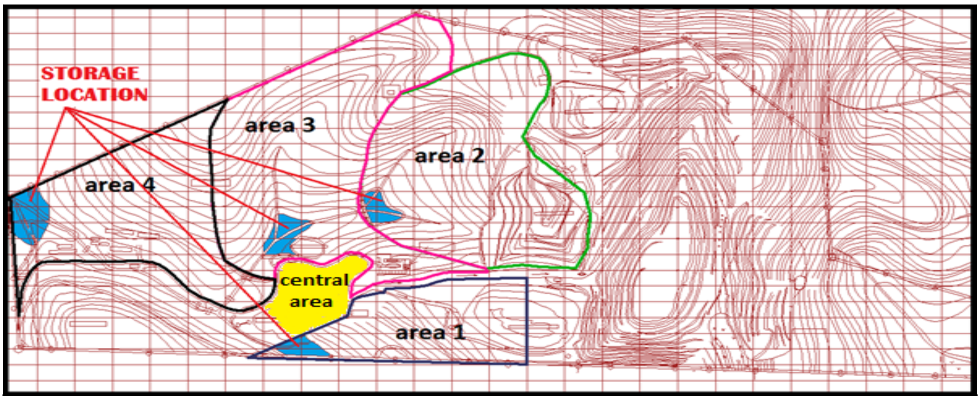


Figure 18: Areas obtained by BMP for water storages

The desigining steps are given below:

- Trying to get as much planar area for storage as possible.
- Minimizing Earthwork as much as possible.
- Aiming to have a fixed storage at each area and drain the rest water to the left side of the road at the entrance to the mine and central planar area covered by mines and the plane strip running along the road as future options

The length, breadth and depth required for each area is calculated using optimization approach to minimize the earthwork and maximize the plane surface.

6.1. Designing as per Rational Method

The depth calculations are shown in table 7.

Table 7: DEPTH CALCULATION BY RATIONAL METHOD

CATCHMENT	VOLUME	LENGTH	BREADTH	DEPTH
A1	116021	100	200	5.80
	116021	125	175	5.30
	116021	150	150	5.15
	116021	175	125	5.30
	116021	200	100	5.80
	Mean DEPTH			**5.47**
A2	273445	200	200	6.83
	273445	225	175	6.94
	273445	250	150	7.29
	273445	275	125	7.95
	273445	300	100	9.11
	Mean DEPTH			**7.62**
A3	300519	200	200	7.51
	300519	225	175	7.63
	300519	250	150	8.01
	300519	275	125	8.74
	300519	300	100	10.01
	Mean DEPTH			**8.38**
A4	209788	100	200	10.48
	209788	125	175	9.59
	209788	150	150	9.32
	209788	175	125	9.59
	209788	200	100	10.48
	Mean DEPTH			**9.89**

6.2. Designing as per SCS-CN Method (2011 data)

Table 8: DIMENSION CALCULATION OF AREA 1

RUNOFF (mm)	AREA (m2)	VOLUME (m3)	LENGTH (m)	BREADTH(m)	DEPTH (m)
1140.78	124700	142255.86	100	200	7.11
1140.78	124700	142255.86	125	175	6.50
1140.78	124700	142255.86	150	150	6.32
1140.78	124700	142255.86	175	125	6.50
1140.783	124700	142255.86	200	100	7.11
939.69	124700	117180.41	100	200	5.85
939.69	124700	117180.41	125	175	5.35
939.69	124700	117180.41	150	150	5.20
939.69	124700	117180.41	175	125	5.35
939.69	124700	117180.41	200	100	5.85
MEAN DEPTH					**6.11**

Table 9: DIMENSION CALCULATION OF AREA 2

RUNOFF (mm)	AREA (m2)	VOLUME (m3)	LENGTH (m)	BREADTH(m)	DEPTH (m)
1025.67	293900	301446.88	100	200	15.07
1025.67	293900	301446.88	125	175	13.78
1025.67	293900	301446.88	150	150	13.39
1025.67	293900	301446.88	175	125	13.78
1025.67	293900	301446.88	200	100	15.07
826.87	293900	243018.22	100	200	12.15
826.87	293900	243018.22	125	175	11.10
826.87	293900	243018.22	150	150	10.80
826.87	293900	243018.22	175	125	11.10
826.87	293900	243018.22	200	100	12.15
MEAN DEPTH					**12.84**

Table 10: DIMENSION CALCULATION OF AREA 3

RUNOFF (mm)	AREA (m2)	VOLUME (m3)	LENGTH (m)	BREADTH(m)	DEPTH (m)
1130.22	323000	365061.57	200	200	9.12
1130.22	323000	365061.57	225	175	9.27
1130.22	323000	365061.57	250	150	9.73
1130.22	323000	365061.57	275	125	10.61
1130.22	323000	365061.57	300	100	12.16
929.20	323000	300134.42	200	200	7.50
929.20	323000	300134.42	225	175	7.62
929.20	323000	300134.42	250	150	8.00
929.20	323000	300134.42	275	125	8.73
929.20	323000	300134.42	300	100	10.00
MEAN DEPTH					**9.27**

Table 11: DIMENSION CALCULATION OF AREA 4

RUNOFF (mm)	AREA (m2)	VOLUME (m3)	LENGTH (m)	BREADTH(m)	DEPTH (m)
1025.67	218500	224110.73	100	200	11.20
1025.67	218500	224110.73	125	175	10.24
1025.67	218500	224110.73	150	150	9.96
1025.67	218500	224110.73	175	125	10.24
1025.67	218500	224110.73	200	100	11.20
826.87	218500	180671.93	100	200	9.03
826.87	218500	180671.93	125	175	8.25
826.87	218500	180671.93	150	150	8.02
826.87	218500	180671.93	175	125	8.25
826.87	218500	180671.93	200	100	9.03
MEAN DEPTH					**9.54**

CHAPTER 7

COMPARISON OF THE METHODS

The Rational Method is the simplest method of runoff computation and can be reasonably assumed as an approximate of all other empirical relations. However it is associated with certain disadvantages and limitations as stated under:

I. The formula is accepted principally to small catchments such that the watershed area is up to a max of fifty square kilometers.
II. Duration of rainfall intensity should be more than the time of concentration of the basin.
III. It gives the peak of the hydrograph but does not provide the complete hydrograph.
IV. It plots a straight line relation between the Peak Discharge and the Rainfall Intensity with intercept zero whereas nature does not allow such a simple equation.
V. Rainfall Intensity must be contact over the entire watershed during the time of concentration.
VI. Coefficient C is assumed to be same for all storms which means the losses are constant for all storms.

However, the Soil Conservation Services – Curve Number method is a much better and robust method which is used for estimation of the volume of runoff. It was observed that the forest cover and hence the land use pattern has changed drastically at the region of consideration over the years. Suitable calculations using the above mentioned formulas were carried out and results were tabulated and then compared with that of the Rational Formula. It was observed that the mean depth obtained from the SCS-CN Method was slightly higher than that obtained from the Rational Method which means that any error committed in the estimation of land use cover and subsequently the curve number would be on the safer side.

Table 12: COMPARISON OF THE DEPTHS

AREA	RATIONAL VOLUME	SCS-CN VOLUME	MEAN DEPTH (RAT)	MEAN DEPTH (SCS)
A1	116062.48	142255.86	5.48	6.12
A2	273542.56	301446.88	7.63	8.59
A3	300626.88	365061.57	8.39	9.28
A4	203365.28	224110.73	9.59	9.54

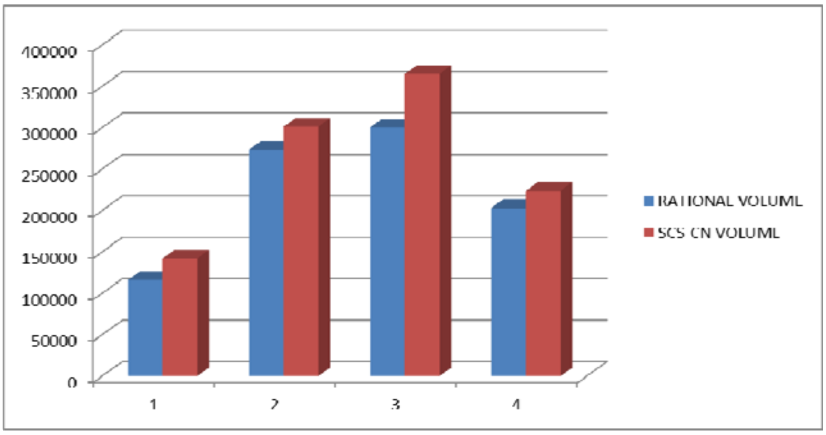


Figure 19: Comparison of runoff volumes in 2005

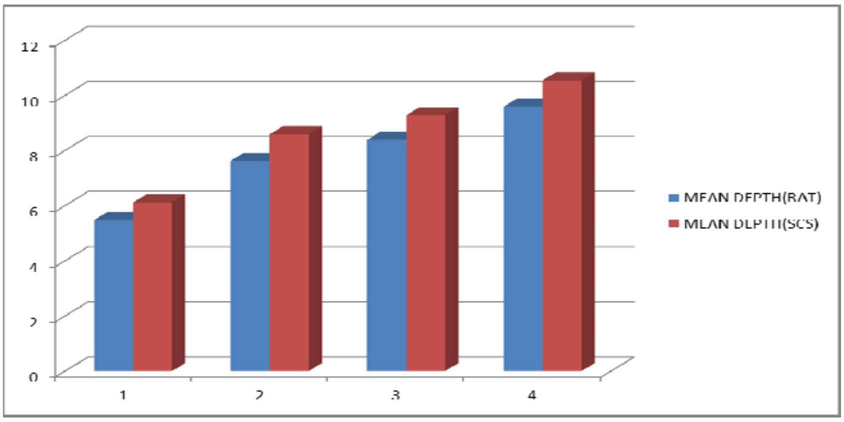


Figure 20: Comparison of runoff volumes in 2011

CHAPTER 8

EARTHWORK CALCULATIONS

Earthwork Calculations are done in cubic meters and generally the length, breadth and height are calculated to give the volume directly (i.e the cubic content). Earthwork of different nature as in excavation of foundation, trenched etc and in filling in plinth and banking are always booked under different headings. Excavation also includes throwing the excavated earth at least 1meter clear of the edge of excavation. Earthwork also depends on the different kinds of soil such as ordinary soil, hard soil; ordinary rock, hard rock etc and they are classified separately and measured under a separate heading. Design or trimming and levelling or grading, ramming and consolidation thickness of each layer etc are also described and included in the item of earthwork.

When the ground is very uneven, levels shall be taken before the start and completion of the earthwork by levelling instrument and average depth of excavation and/or filling shall be determined from these levels. Whenever it is not possible or convenient to make measurements form cutting, the filling or banking shall be measured and deduction for shrinkage or voids (settlement allowances) shall be made from actual measured cubic contents depending on the nature of soil and methods of consolidation. Generally 10% deduction shall be made in case of ordinary consolidated fills and in case of consolidation done by heavy machinery; a deduction of 5% shall be made. However, no separate measurements are taken for setting out works, profiles, site clearance, deadmen, stepping, removal of slips or falls, bailing out water from rains, etc., these are included in the rate of earthwork.

The various steps included in the execution of earthwork measurement are as follows:

i. Foundation Trench
ii. Return, Fill and Ram
iii. Puddling
iv. Surface Dressing
v. Surface Excavation
vi. Pumping
vii. Timbering

In any case of measurement of earthwork quantity, generally the measurements are taken separately for every 30m lead or distance and every 1.5 m lift or height of depth. The lead shall be measured from the centre of the area of excavation to the centre of the area of soil heap; similarly the lift shall be measured from the centre of soil excavation to the centre of the soil heap. *I.S.I specifies the unit of lead as 50m, measured over the shortest practicable route.*

- For our consideration, the cost of earthwork around Rourkela was observed to be Rs. 48.96/m3.
- Since the Tensa region has a hilly terrain, the cost of earthwork was assumed to be nearly double because of the difficulties of hilly terrain and rate used was = Rs. 97.92/m3.
- Since the same amount of earth obtained from cutting was used for filling, so cost of filling is assumed to be negligible. However for the consideration of safety and buffer charge and *additional 10%* was used as the factor of safety.

Mathematically, The volume of earthwork required in cutting is calculated as

$$V = \tfrac{1}{2} \times (A \cos a)/2 \times H/2;$$
$$= A*H / 8; \qquad \text{as} \quad \cos a \approx 1$$

Where ,

V = Volume of Earthwork in Cutting
A = Area bounded between the contours
H = Height difference between contours
a=Slope of terrain

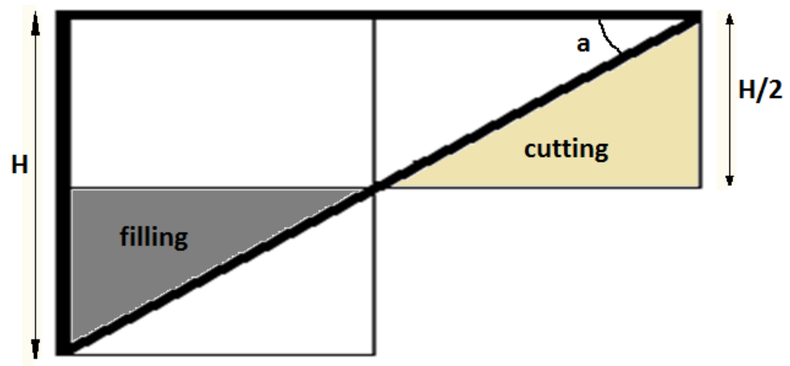


Figure 21: Earthwork Calculation

The cost of earthwork is calculated as

$$C = V * 97.92 * 1.1;$$

where C= Total Cost of Earthwork in Rupees

Next, for different heights of contours considered, the net volume of earthwork in each sub basin was calculated assuming a triangular cross-section throughout to minimize the earthwork volume and to ensure equal volumes of cutting and filling. This resulted in different scenarios for the earthwork costs for the storage areas which are to be presented to the client.

Table 13: EARTHWORK COST CALCULATION
(a- AREA 1 ; b-AREA 2 ; c-AREA 3 ; d-AREA 4)

(a)

CONTOUR HEIGHT (m)	AREA (m^2)	VOLUME (m^3)	EARTWORK ESTIMATE (Rs)
5	5654.8	3534.25	380681.13
10	8629.71	10787.13	1161904.15
15	10260.47	19238.38	2072204.52

(b)

CONTOUR HEIGHT (m)	AREA (m^2)	VOLUME (m^3)	EARTWORK ESTIMATE (Rs)
10	7301.2	9126.5	983033.56
15	16640.59	31201.10	3360733.55

(c)

CONTOUR HEIGHT (m)	AREA (m^2)	VOLUME (m^3)	EARTWORK ESTIMATE (Rs)
5	19864.43	12415.26	1337273.42

(d)

CONTOUR HEIGHT (m)	AREA (m^2)	VOLUME (m^3)	EARTWORK ESTIMATE (Rs)
5	11039.3	6899.56	743165.67
10	28094.62	35118.27	3782659.63

A comparison of the minimum cost of earthwork for the different areas are given below :

Table14: COST OF MIN EARTHWORK AT AREAS

AREAS	VOLUME (m^3)	COST OF EARTHWORK (Rs.)
A1	3534.25	380681.13
A2	9126.5	983033.56
A3	12415.26	1337273.42
A4	6899.56	743165.67

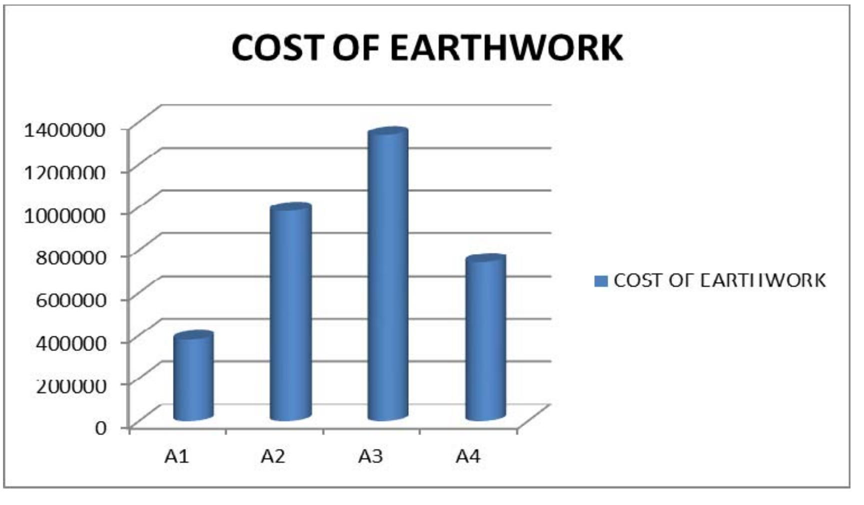


Figure 22: Cost of Earthwork

CHAPTER 9

WATER QUALITY ANALYSIS

Water quality is the physical, chemical and biological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose. Water quality determines the 'goodness' of water for particular purposes. Water quality tests will give information about the health of the waterway. By testing water over a period of time, the changes in the quality of the water can be seen. Parameters that may be tested include temperature, ph, turbidity, salinity, nitrates and phosphates. An assessment of the aquatic macroinvertebrates can also provide an indication of water quality.

TEMPERATURE

Temperature of a water is significant because it affects the amount of dissolved oxygen in the water. The amount of oxygen that will dissolve in water increases as temperature decreases. Water at O˚C will hold up to 14.6 mg of oxygen per litre, while at 30˚C it will hold only up to 7.6 mg/L.

SALINITY

Salinity is a measure of the dissolved salts in the water. Salinity is usually highest during periods of low flows and increases as water levels decrease. Salinity is measured as either TDS (Total Dissolved Solids), which measures the amount of dissolved salts in the water, or as EC (Electrical Conductivity), which is the property of a substance which enables it to serve as a channel or medium for electricity. Sources of salinity include urban and rural run-off containing salt, fertilisers and organic matter. Land use issues related to high levels of salinity include clearing of vegetation and the resultant rise in the water table, excessive irrigation, groundwater seepage and runoff containing dissolved solids from industry, sewage, agriculture and stormwater. Water containing a TDS level of over 500 mg/L is unsuitable for irrigation of many plants and tastes unpleasant to drink. High levels of salinity in water may have adverse impacts upon fresh water flora and fauna, which are not salt tolerant. High levels of salinity also have implications when using water for stock watering.

pH

pH is a measure of the acidity or alkalinity of water. It is usually measured by using a colorimetric test - litmus paper changes colour with increased acidity or alkalinity. pH varies naturally within streams as a result of photosynthesis. Extreme values of pH can cause problems for aquatic fauna. Death of most aquatic fauna may result from extremely acid or alkaline water. A ph range of 6.5 – 8 is optimal for freshwater. A range of 8 – 9 is optimal for estuarine and sea water.

TURBIDITY

Turbidity is a measure of the ability of light to pass through water, that is, a measure of the water's murkiness. Measuring murkiness gives an estimate of suspended solids in the water. Suspended Solids usually enter the water as a result of soil erosion from disturbed land or can be traced to the inflow of effluent from sewage plants or industry. Suspended solids also occur naturally in the water from bank and channel erosion; however, this process has been accelerated by human use of waterways. Pollutants such as nutrients and pesticides may bind with suspended solids and settle in bottom sediments where they may become concentrated. Suspended sediments can also smother aquatic plants as they settle out in low flows, and clog mouthparts and gills of fish and aquatic macroinvertebrates. Though high turbidity is often a sign of poor water quality and land management, crystal clear water does not always guarantee healthy water. Extremely clear water can signify very acidic conditions or high levels of salinity.

DISSOLVED OXYGEN (DO)

The amount of oxygen in water, to a degree, shows its overall health. That is, if oxygen levels are high, one can presume that pollution levels in the water are low. Conversely, if oxygen levels are low, one can presume there is a high oxygen demand and that the body of water is not of optimal health. Apart from indicating pollution levels, oxygen in water is required by aquatic fauna for survival. In conditions of no or low oxygen availability, fish and other organisms will die.

BOD AND COD

The Biological Oxygen Demand (BOD) is the amount of oxygen consumed by bacteria in the decomposition of organic material. It also includes the oxygen required for the oxidation of various chemical in the water, such as sulfides, ferrous iron and ammonia. While a dissolved oxygen test tells you how much oxygen is available, a BOD test tells you how much oxygen is being consumed. The chemical oxygen demand (COD) is used as a measure of the oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant.

NUTRIENTS

The three main plant nutrients are nitrogen, phosphorus and potassium. Of these, only phosphorus is tested by Waterwatch groups. However, due to human impacts these levels are often too high, resulting in algal blooms and excessive growth of water-plants including weed species such as Water Hyacinth and Salvinia.

FAECAL COLIFORMS

Faecal Coliforms are naturally occurring bacteria found in the intestines of all warm blooded animals (including humans) and birds. The presence of Faecal Coliforms is an indicator of contamination by sewage waste. Faecal Coliforms indicate a risk to human health. They are not pathogenic (disease causing) but indicate that pathogenic bacterial and viruses may be present. Faecal Coliforms can enter streams and rivers via sewer and septic systems , feedlot and dairy run-off , run-off from broad acre farming , storm water, livestock defecating directly into the water .

Water Quality report from Tensa was analyzed. The results were compared with desirable limits as per IS-10500. The physical and chemical parameters are shown in table below. Our prime concern is water sample from colony areas which will be chiefly used for drinking purposes. As seen from the table the samples W1 and W2 have all the physical and chemical parameters within the permissible limits. Hence the storage structures that will be built near the colony will be safe for drinking and household purposes. The samples from W3, W4 and W5 have turbidity above desirable limits but it’s within the permissible limit i.e. 10. So it is acceptable .Whereas water from GW3 needs to be treated for turbidity. The iron content in samples of W3, W4, W5, W5, SW1 and SW2 are above acceptable limit.

The water is found free from mineral oil, Mercury as Hg, Arsenic as As, Zinc as Zn, Cadmium as Cd, Selenium as Se ,Cyanide as CN ,Copper as Cu, Phenolic Compound as C6H5OH, Lead as Pb ,Pestisite ,total chromium as Cr, diss. Phoshate as P , Sulphide and hexa chromium. Hence there is no toxic content in water samples collected. The sample W5 has some oil and grease above the permissible limit.

Faecal Coliforms are naturally occurring bacteria found in the intestines of all warm blooded animals (including humans) and birds. The presence of Faecal Coliforms is an indicator of contamination by sewage waste. But total choliform level in all the samples is NIL.

Table 15
DRINKING WATER QUALITY ANALYSIS REPORT
SIX MONTHS AVERAGES FROM APRIL 2010 TO SEPTEMBER 2010

Sl. no.	PARAMETERS	UNIT	STANDARD AS PER IS-10500	RESULTS										
				W1	W2	W3	W4	W5	W6	SW1	SW2	GW1	GW2	GW3
	PHYSICAL													
1	Colour	hazen	5	CL	CL	<10	<10	<10	<10	<10	<10	NIL	NIL	NIL
2	Odour	–	Unobjectable	Unobjectable	Unobjectable							Unobjectable	Unobjectable	Unobjectable
3	Taste	–	Agreeable	Agreeable	Agreeable							Agreeable	Agreeable	Agreeable
4	Turbidity	NTU	5	1.83	1.94	7.29	7.89	8.78	3.2	3.54	3.67	1.95	1.79	27.77
5	Temperature	˚C	–	25	25	25	25	25	25	25	25	25	25	25
6	Total Dissolved Solids	mg/l	500	99.83	99.83	92.83	85.5	115.83	142.68	88.83	84.5	96.33	99.33	100.83
7	Electrical Conductivity	µmho/cm	–	149	148.67	87.67	92	115	142.68	133.5	130	143.5	147.17	150.17
8	Total Hardness	mg/l	300	19.1	20.45	138	126.67					16.62	15.9	17.15
	CHEMICAL													
9	Ph	–	6.5-8.5	7.12	7.2	7.18	7.12	6.92	7.12	7.28	7.17	7.23	7.12	7.22
10	Calcium as Ca	mg/l	75	7.43	7.41	7.1	7.21	15.18	6.99	5.99	6.39	6.47	7.22	6.91
11	Magnesium as Mg	mg/l	–	1.67	1.77	1.25	1.28	6.48	1.91	2.17	2.3	1.96	1.88	1.89
12	Residual Free Chlorine	mg/l	0.2	ND	ND	ND	ND	BDL	BDL	BDL	BDL	BDL	BDL	BDL
13	Free CO2	mg/l	–	2.38	2.5	0.74	13.23	2.07	1.17	1.38	1.29	1.44	1.59	1.51
14	Sulphates	mg/l	200	8.13	8.06	1.48	1.62	4.08	1.7	1.61	1.54	2.5	2.46	2.34
15	Chlorides	mg/l	250	7.39	7.51	5.54	6.4	11.54	7.16	4.17	4.25	5.57	6.1	6.08
16	Fluorides	mg/l	1	0.04	0.03	0.06	0.069	0.06	0.069	0.06	0.073	0.055	0.044	0.047
17	Acidity	mg/l	–	5.93	6.05	3.44	4.02	19.81	4.37	4.5	4.02	4.32	4.02	4.12
18	Alkylinity	mg/l	200	12.45	13.04	17.38	19.02	23.03	16.24	12.86	14.24	13.07	13.35	12.36
19	Iron as Fe	mg/l	0.3	0.14	0.15	0.54	0.67	0.54	0.67	0.57	0.61	0.13	0.12	0.14
20	dissolved oxygen	mg/l	4			7	6.62	5.7	6.7	6.87	6.7			
21	BOD	mg/l	3			1.24	1.33	15.64	2.07	1	1.22			
22	COD	mg/l	–			6.89	7.7	20.92	3.1	2.03	2.26			

W1-BORE WELL AT COLONY **W2-**TAP WATER AT COLONY **W3-**SAMIJI NALA UPSTREAM OF MINES
W4-SAMIJI NALA DOWNSTREAM OF MINES **W5-**MINE DRAINAGE WATER **W6-**MINE DRAINAGE WATER AFTER TREATMENT
SW1-BARSUAN NALA NEAR RAIWAY SIDING **SW2-**BARSUAN NALA
GW1-WELL WATER AT RAIKELA VILLAGE **GW2-**WELL WATER AT BANDHAL VILLAGE **GW3-**WELL WATER AT ZERO POINT

CHAPTER 10

RESULTS AND CONCLUSIONS

Implementation of rainwater harvesting is essential to fulfill the increasing water consumption by the industry, maintenance of dust due to crushing of rocks, plantations, vegetation and household users in the study region. The present work implies the hydrological analysis in association with GIS support to obtain the water availability and its proper storage at four different locations. Various scenarios were developed, which are really useful for the Management Authorities for its proper management and utilization. The approach can be utilized for similar basins in India.

The region under consideration, Tensa, had an ample amount of rainfall annual as well as monsoon. Further, rainwater harvesting possibilities were successfully estimated using the Rational as well as SCS-CN approaches and different scenarios were generated at the apt sub basins assessed using the ridge lines from topographical analysis. Subsequently, suitable locations of storage reservoirs for each of the basins were projected and different dimensions were tried using Best Management Practices and optimization of earthwork and other costs involved. The scenarios so generated were tabulated and would be presented to the client for final review, sanctioning and application. However, we identified the best possible location of reservoirs at each of the subareas and alongside concluded that the height of the reservoir at each of the location is the minimum contour difference at that sub basin i.e. five meters for areas one, two and four and ten meters for area 3.

Alongside, the water quality analysis carried out showed that all the parameters lied within the standards permitted avoiding any risk to human and environment. Though values at certain regions were found to be significantly higher than that at other regions, it was attributed to the fact that these are located nearer to the emission sites.

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